

OPTICAL SENSOR ASSEMBLAGE AND
CORRESPONDING MANUFACTURING METHOD

Background Information

The present invention relates to an optical sensor assemblage and a corresponding manufacturing method.

Although applicable to any optical sensor assemblages, the present invention and the problem
5 on which it is based will be explained with reference to a thermopile sensor assemblage.

Thermopile sensors belong to the group of thermal radiation sensors, i.e. an incident radiation
results in a temperature difference between a receiver surface and a difference region (heat
sink). This temperature difference is converted into an electrical voltage with
thermoelements, on the basis of the Seebeck effect. The output voltage depends not on the
10 geometric dimensions of the thermoelements, but only on the material combination selected.
The output voltage of the thermopiles thus implemented is increased by serially connecting
multiple identically irradiated thermoelements.

Using micromechanical technologies, it is possible to manufacture the thermopiles as silicon
chips, similarly to conventional semiconductor components and using typical semiconductor
15 processes. The application of multi-level technologies additionally permits a further reduction
in the geometric dimensions of the thermopiles. To achieve maximum sensitivity, the
thermopiles are provided on a thermally insulating membrane that is as free-standing as
possible. An etched silicon frame serves as carrier for the membrane and simultaneously as a
thermal reference medium.

20 Conventional micromechanical thermopile sensors with, for example, an infrared filter for gas
detection are installed in TO05 or TO08 packages having optical windows. The thermopile
element sits with its optically inactive side on the housing base, while the filters are
adhesively bonded in the TO cap. Essential sensor properties such as sensitivity, time
constant, and acquired spectral range can be influenced, during packaging of the sensors in
25 hermetic metal housings of this kind, by selection of the filter medium and window material.

This type of housing is very expensive and is also no longer hermetically sealed because of the necessary openings in the cap. There is generally no passivation of the bonding wires, which calls into question suitability for outdoor applications, in particular automobile applications, due to condensation, corrosion, etc.

- 5 Also known are completely injection-embedded or molded sensors, e.g. micromechanical acceleration sensors. Here the sensor element is secured (adhesively bonded or soldered) at its inactive rear side onto a carrier strip (lead frame). Wire-bond connections are used to create an electrical contact on contact surfaces (called "leads") provided therefor on the rim of the chip mounting surface. The lead frame is then injection-embedded or molded using a plastic
- 10 compound or molding compound. Because the molding compound is insufficiently transparent in the frequency range of interest for thermopile sensors for gas detection (e.g. in the infrared region at wavelengths greater than or equal to 4000 nm), optical access to the sensor would no longer exist with an installation technique of this kind (complete injection embedding).
- 15 Lastly, IC housings for power ICs, having an exposed chip installation region (called a "die pad") on the rear side for purposes of better heat dissipation, are known.

Advantages of the Invention

- The optical sensor assemblage according to the present invention having the features of Claim 1, and the corresponding manufacturing method according to Claim 16, exhibit the advantage,
- 20 as compared with the known approaches to a solution, that they make possible simple and very economical assembly, all the bonded connections being passivated. This yields a sensor suitable for automobile applications.

- The underlying idea of the present invention is to provide a packaging device, for example in the form of a moldable housing, having an optically open region, in the form of a window on the chip mounting surface, in which is provided an optical sensor that is exposed substantially
- 25 only through the window to optical radiation that is to be detected.

- As compared with a known package having a cavity on the upper side, in which context assembly tolerances in the configuration can be very large and a male die must protect the active chip surface from the molding compound, with the sensor assemblage according to the
- 30 present invention there is no need for a male die that presses directly onto the chip and might

possibly damage it. Only the window in the chip receiving region must be protected from the packaging material (e.g. plastic or molding compound). Passivation using a non-transparent standard molding compound is possible, so that no further passivation material is needed. In the case of mounting onto a substrate, the possibility exists of applying further optical filters onto the substrate or the package itself. Replaceable or retrofittable filters, for example, can thus be provided.

The dependent claims contain advantageous developments of and improvements to the respective subject matter of the invention.

According to a preferred development, the sensor chip assemblage has a first chip having a first and a second oppositely located surface, and a second chip having a third and a fourth oppositely located surface, which chips are joined via the first and the third surface and enclose a cavity in which the sensor structure is disposed; and the first chip has on the first surface a contact region for wire bonds which protrudes laterally beyond the second chip (bonding region) and onto which at least one bonding wire bonded to a connector element (lead) is guided.

According to a further preferred development, the optically transparent irradiation region and the surrounding mounting region are provided on the second surface (base surface) of the first chip.

According to a further preferred development, the optically transparent irradiation region and the surrounding mounting region are provided on the fourth surface of the second chip.

According to a further preferred development, the chip receiving region (e.g. the die pad of a lead frame that is used) has a fifth and a sixth oppositely located surface, the fifth surface being joined to the mounting region.

According to a further preferred development, the sixth surface is not covered by the packaging device and lies in one plane with a lower side of the packaging device.

According to a further preferred development, the connector elements protrude out of oppositely located lateral surfaces of the packaging device, their ends lying (e.g. in accordance with the standard for molded housings) in the plane of the lower side.

According to a further preferred development, the sixth surface and the ends of the connector elements are joined (e.g. adhesively bonded or soldered) to a substrate that has a through hole in the region of the window.

5 According to a further preferred development, the sixth surface is partially covered by the packaging device, and a lower side of the packaging device lies in a plane below the sixth surface.

According to a further preferred development, an optical filter device is provided on the second or fourth surface of the first chip and/or on the substrate in the region of the through hole.

10 Drawings

Exemplifying embodiments of the invention are depicted in the drawings and explained in more detail in the description below. In the drawings:

Figures 1a-d show a first embodiment of the sensor apparatus according to the present invention and its configuration;

15 Figures 2a, b show a second embodiment of the sensor apparatus according to the present invention and its configuration;

Figures 3a-d show a third embodiment of the sensor apparatus according to the present invention and its configuration; and

20 Figures 4a, b show a fourth embodiment of the sensor apparatus according to the present invention and its configuration.

Description of the Exemplary Embodiments

In the Figures, identical reference characters designate identical or functionally identical components.

The embodiments below describe, with no limitation of generality, an optical sensor assemblage for an optical thermopile sensor for automobile applications. The examples concern in particular a micromechanical optical thermopile sensor having an integrated filter for detecting infrared radiation in the wavelength region greater than or equal to 4000 nm, for gas detection (CO₂ sensor).

Figures 1a-d show a first embodiment of the sensor apparatus according to the present invention and its configuration.

In Figure 1a, reference number 10 designates in general an optical sensor assemblage in the form of a thermopile sensor assemblage. Sensor assemblage 10 encompasses a lower chip 1a having a cavity 2a above which is provided a membrane M. Applied on membrane M are thermopile sensor elements TP and an absorber layer A located thereabove. By way of a conductive strip LB, an electrical connection is guided from thermopile elements TP into the outer rim region of first chip 1a, which hereafter will also be referred to as wire-bond region BB.

A second chip 1b is bonded with its surface O3 onto upper surface O1 of first chip 1a as a cap, second chip 1b likewise having a cavity 2b that is oriented toward cavity 2a of the first chip. Second chip 1b is dimensioned and oriented in such a way that it leaves wire-bond region BB of first chip 1a exposed. Filter layers FS for filtering out specific wavelengths are applied onto lower surface O2 of first chip 1a.

It may be noted with regard to this first embodiment that the silicon of first and second chips 1a, 1b is sufficiently transparent for the optical wavelengths in the middle infrared region that are to be sensed. In usual thermopile elements TP, the optical radiation to be sensed is directed directly onto absorber layer A. With the configuration according to Figure 1, this would mean that the optical radiation would need to be directed toward upper surface O4 of second chip 1b.

In contrast to this usual procedure, however, in this first embodiment optical irradiation region OB is defined on surface O2 and extends, because of the configuration, over the diameter of absorber layer A and of thermopile elements TP located therebelow. Experiments have indicated that the losses occurring because of this type of irradiation due to thermopile elements TP themselves are relatively small, and constitute only a few percent of the total radiation yield.

The central optical irradiation region OB on surface O2 is surrounded annularly by a mounting region RB that is employed, as explained in detail below, for mounting of this sensor assemblage 10, the optical irradiation region being left exposed.

Figure 1b is a plan view of surface O2 of first chip 1a (without filter layer FS). Cavity 2a, optical irradiation region OB, mounting region RB, and wire-bond region BB located on the oppositely located surface O1 are highlighted by the dashed lines.

According to Figure 1c, sensor assemblage 10 according to Figures 1a, b is adhesively bonded or soldered, by a mounting region LBR, onto a mounting frame MLF in the form of a usual lead frame. Mounting frame MLF encompasses for that purpose a chip receiving region DP equipped with a window F, as well as a plurality of connector elements or connector legs AB. Not depicted in the sectioned view of Figure 1c is the suspension of chip receiving region DP on corresponding connector elements, usually in the corners of mounting frame MLF.

Upon assembly of sensor chip assemblage 10, mounting region RB that annularly surrounds optical irradiation region OB is joined to chip receiving region DP in such a way that optical irradiation region OB is not covered by chip receiving region DP, i.e. is exposed toward the outside through window F.

In addition, connector elements AB are connected via corresponding bonding wires BD to conductor path LB and to further conductor paths (not shown) on corresponding bonding surfaces.

In a subsequent step, after completion of all the connecting operations and soldering or adhesive bonding operations, sensor assemblage 10 is injection-embedded into a molded package MV. In this context, lower side US of molded package MV extends in one plane substantially flush with a lower surface O6 of chip receiving region DP, surface O6 being located opposite a surface O5 onto which mounting region RB of chip 1a is mounted. The join between chip 1a and chip receiving region DP must be sealed for the molding process.

Connector elements AB project out of lateral surfaces SS1, SS2 of molded package MV whose planar upper side is labeled OS, and are bent upward or downward in usual fashion.

This type of assembly yields a sensor assemblage 10 in which optical radiation can be incident onto thermopile elements TP and absorber layer A substantially only through

window F, since molded package MV and the metallic mounting frame MLF are not transparent to, or have a shielding effect on, the relevant optical radiation.

Lower side US of molded package MV is also substantially in one plane with the ends of connector elements AB' (in accordance with the JEDEC standard for SOP-form molded housings).

Referring now to Figure 1d, sensor assemblage 10 packaged in this fashion can be soldered onto a substrate SUB that has a corresponding through hole DL in the region of window F. Corresponding soldering regions LBR can be provided not only on contact elements AB but also on the exposed lower surface O6 of chip receiving region DP; this additionally enhances the stability of the assemblage and ensures good thermal contact with substrate SUB. This possibility of additionally soldering or adhesively bonding the packaged sensor assemblage at chip receiving region DP that is exposed on surface O6 brings about not only greater stability but also better dynamic coupling to substrate SUB.

Furthermore, an additional filter device FI can optionally be provided on a surface of substrate SUB and in through hole DL. This additional filter device can also, for example, be configured replaceably or adjustably, thus additionally enhancing the flexibility of the sensor assemblage.

Figures 2a, b show a second embodiment of the sensor apparatus according to the present invention and its configuration.

In the second embodiment shown in Figure 2a, molded package MV' is configured differently than in the first embodiment according to Figure 1c. In particular, molded package MV' here has a lower side US' that lies in a lower plane than lower surface O6 of chip receiving region DP, which in turn is also partially covered by molded package MV'.

In this embodiment as well, lower side US' of molded package MV' is substantially in one plane with the ends of connector elements AB', and leaves at least window F in optical irradiation region OB of sensor assemblage 10 exposed through an opening MA. In terms of method, lower surface O6 of chip receiving region DP can be left exposed by providing an appropriate male die on the molding tool in this region during molding, chips 1a, 1b being protected from the male die by mounting frame MLF.

Referring to Figure 2b, this assemblage can once again be mounted, by way of corresponding soldering regions LBR, via connector elements AB', onto a substrate SUB' that can have a corresponding filter device FI'. In the exemplifying embodiment according to Figure 2b, through hole DL' of substrate SUB' is provided with a larger diameter than in the first
5 embodiment above, which increases the solid angle for irradiation of optical irradiation region OB.

Figures 3a-d show a third embodiment of the sensor apparatus according to the present invention and its configuration.

The third embodiment of the present invention shown in Figure 3a differs from the first and
10 second embodiments explained above especially in that optical irradiation region OB' is located on fourth surface O4 of second chip 1b, i.e. on the latter's upper surface. In this third embodiment, absorber layer A is therefore irradiated in the usual fashion. What results accordingly is an annular, asymmetrical mounting region RB' that surrounds optical irradiation region OB. Also in this embodiment, filter layers FS' are provided not on second
15 surface O2 but, corresponding to optical irradiation region OB', on fourth surface O4.

The further components of Figure 3a otherwise correspond to the components already explained in connection with Figure 1a.

Optical irradiation region OB', mounting region RB' that surrounds the latter (asymmetrically in some circumstances), and wire-bond region BB are evident in the plan view of this sensor
20 apparatus from above as shown in Figure 3b, respective enlarged wire-bond regions BP1, BP2, BP3 (also called "bonding pads") being provided at the ends of conductor paths LB.

As depicted in Figure 3c, analogously to the first embodiment according to Figure 1c fourth surface O4 is mounted, via filter region FS' and a mounting region LBR (adhesive bonding or soldering) onto chip receiving region DP' in such a way that window F' of chip receiving
25 region DP' leaves optical irradiation window OB' of sensor assemblage 10' exposed.

As is clearly evident from Figure 3c, asymmetrical mounting region RB' causes the orientation of window F' in chip receiving region DP' also to be disposed asymmetrically with respect to the latter's center. Wire-bond region BB, in particular, is offset laterally with respect to chip receiving region DP' in order to make possible contacting of connector
30 element AB" in simple fashion by bonding wire BD.

After assembly of the chip and contacting with wires, injection-embedding into molded package MV'' is accomplished analogously to the first embodiment according to Figure 1c; once again, lower surface O6 of chip attachment region DP' extends in one plane with lower side US of molded package MV'' and is completely exposed. Connector elements AB'' also
5 extend at their ends in the region of this plane per JEDEC standard, as is clearly apparent from Figure 3c.

Referring to Figure 3d, the chip assemblage constructed in this fashion is mounted on a substrate SUB'' having a through opening DL'' analogous to the through opening shown in Figure 1d. Joining is accomplished via soldering regions LBR between connector elements
10 RB'' and substrate SUB'', and optionally between surface O6 of chip receiving region DP' and substrate SUB''.

An optional filter device FI'' is also provided on the side of substrate SUB'' facing away from chip assemblage 10'.

Figures 4a, b show a fourth embodiment of the sensor apparatus according to the present
15 invention and its configuration.

Referring to Figure 4a, in this fourth embodiment lower side US' extends in a plane below surface O6 of chip receiving region DP'. An opening MA' in molded package MV''', which leaves window F' and thus optical irradiation region OB' exposed, is correspondingly provided.

20 Lastly, referring to Figure 4b, with this embodiment a mounting of the packaged chip assemblage 10' onto a substrate SUB''' is performed, analogously with Figure 3b, via connector elements AB''' and soldering regions LBR.

Here as well, filter device FI''' is provided on the side of the substrate facing away from the chip assemblage.

25 Although the present invention has been described above with reference to a preferred exemplifying embodiment, it is not limited thereto but rather is modifiable in multifarious ways.

Although not shown in the above embodiment, the connector elements can of course be oriented in any desired directions with respect to chip receiving region DP, so that a "reverse" mounting on the substrate is also possible and the substrate does not require a window.

5 It is also possible for the chip assemblage to be not soldered, but rather adhesively bonded, onto the mounting frame.

Alternative or additional filter assemblages can furthermore be applied onto the exposed surface of the chip receiving region.